Lower Ordovician arthropod Trace Fossils from western New South Wales

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WEBBY, B. D. Lower Ordovician arthropod trace fossils from western New South Wales. *Proc. Linn. Soc. N.S.W.* 107 (2), (1982) 1983: 61-76.

Eight trace fossil species attributed to the activity of arthropods are described and illustrated from the Lower Ordovician (Tremadoc-Arenig) clastic succession of western New South Wales. They include the new species *Cruziana warrisi, Diplichnites binatus* and *Rusophycus latus.* A number of different arthropods would seem to have been responsible, but not necessarily trilobites. The *Diplichnites* sp. A trackway is some 185 mm wide, suggesting a very large arthropod, larger than any known trilobite from accompanying beds of the N.S.W. Lower Ordovician succession. *R. latus* is the most common type of arthropod activity in the N.S.W. Lower Ordovician succession (Bynguano Quartzite and Scopes Range Beds). It closely resembles the *Rusophycus* found in central Australia — in the Pacoota Sandstone of the Amadeus Basin and the Tomahawk Beds of the Georgina Basin. The western N.S.W. arthropod traces are associated in shallow marine deposits with *Skolithos, Arthrophycus, Diplocraterion* and other unnamed trace fossils. A preliminary Lower-Middle Ordovician arthropod ichnostratigraphy is outlined based on these and other known Australian occurrences.

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manuscript received 8 February 1983, accepted for publication 20 April 1983.

INTRODUCTION

Of the many trace fossils preserved in Lower Palaeozoic clastic successions of Australia, those attributed to the activity of arthropods are among the most distinctive and common. They include such forms as *Cruziana, Dimorphichnus, Diplichnites, Merostomichnites, Monomorphichnus, Protichnites* and *Rusophycus.* The structure attributed by Woods (1862) to *Cruziana cucurbita* Salter appears to be the first record of a Lower Palaeozoic arthropod trail from Australia. It was not however until nearly one hundred years later that it became generally realized how widespread and abundant such occurrences were. Glaessner (1957) drew attention to the numerous occurrences of *Cruziana* in the Cambrian of South Australia and the Ordovician of central Australia, and many authors have since recorded such arthropod traces from these and other Lower Palaeozoic sequences. But few have yet carried out detailed studies of these trace fossils, or attempted to establish their stratigraphic or palaeoenvironmental potential.

In western New South Wales, Lower Ordovician arthropod traces were first noted from the Bynguano Range of the Mootwingee area by Wilson (1967) and Warris (1967, unpubl.), and from the Scopes Range by Rose and Brunker (1969). In the Bynguano Range, *Cruziana* was recorded from the Bynguano Quartzite (Warris, 1967, unpubl.; Shergold, 1971; in part the Lingula Beds of Wilson, 1967). However the morphological appearance of these most common arthropod traces in the Bynguano Quartzite are more properly identified as representatives of *Rusophycus,* as Pogson and Scheibner (1976) have already noted. Rose and Brunker (1969) and Webby (1974, unpubl.; 1977) reported the same variety of *Rusophycus* from the Scopes Range Beds at Scopes Range. The only trace fossil previously illustrated from the Ordovician of western New South Wales is a *Rusophycus* which was erroneously assigned a Cambrian age (Hill, 1972, fig. 10a).

STRATIGRAPHY

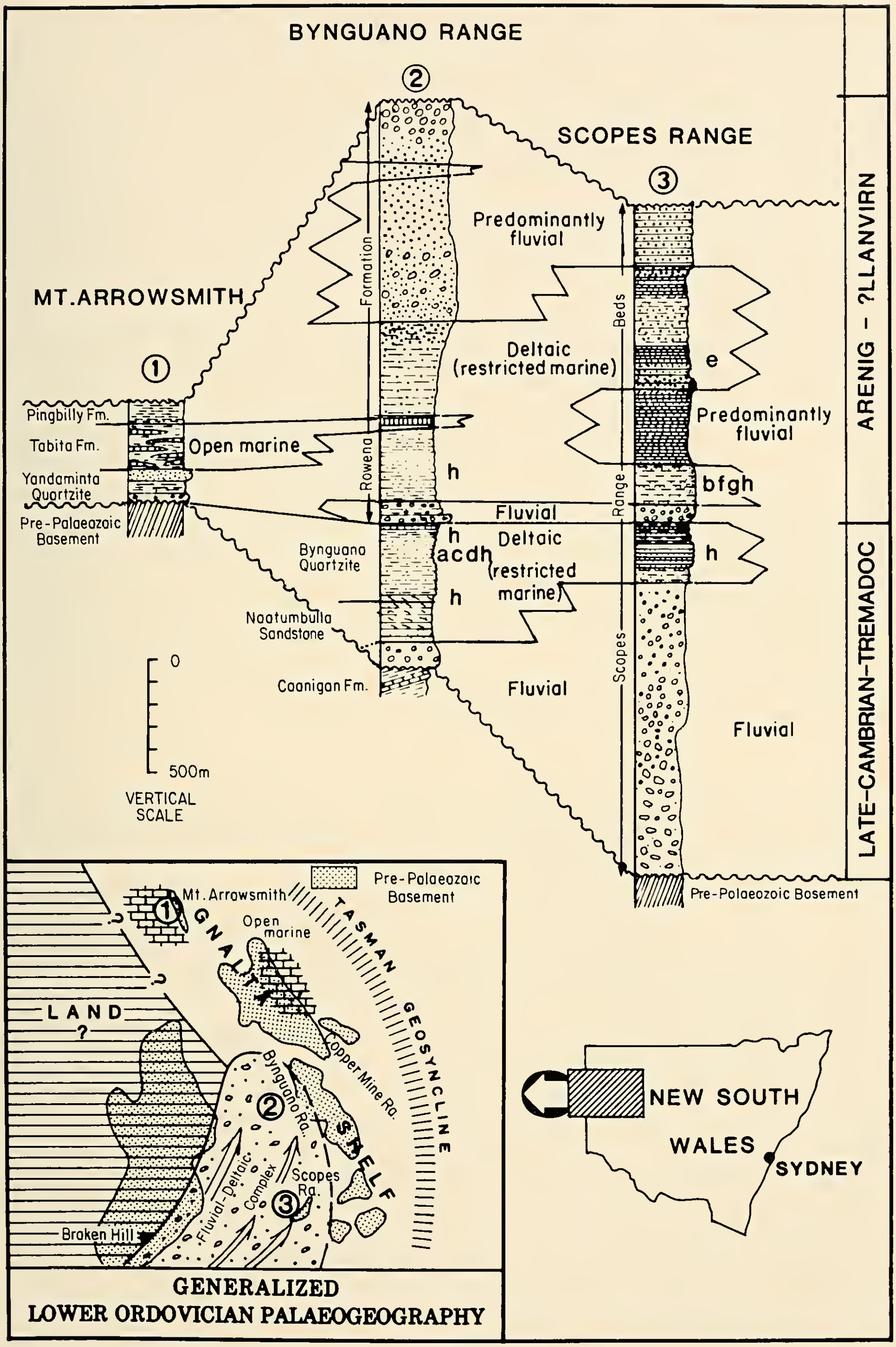
The stratigraphical terminology for the uppermost Cambrian-Lower Ordovician of western New South Wales is based on Warris (1967, unpubl.) and Rose (1968). In the Bynguano Range, the sequence comprises in ascending order, the Nootumbulla Sandstone, the Bynguano Quartzite and the Rowena Formation (Webby, *in* Shergold *et al.*, 1982, text-fig. 8). The Bynguano Quartzite is 305 m thick and the Rowena Formation, 1685 m thick. The Rowena Formation is a predominantly quartzitic sandstone succession but has some interbedded conglomerates and thin, impure limestones. In the Scopes Range, the sequence of Scopes Range Beds includes a lower, 1200 m thick 'non-marine' conglomerate unit overlain by a 1650 m thick alternating 'shallow marine' to 'non-marine' (fluvial) sandstone unit. Correlations between the successions of the two areas have been represented by Webby (1978, fig. 3; *in* Shergold *et al.*, 1982, text-fig. 9).

Rusophycus latus is common throughout the Bynguano Quartzite and occurs again in the lower part of the overlying Rowena Formation, up to the level of the thin, impure limestone beds. Other arthropod traces occur only rarely in the Bynguano Quartzite. They include *Cruziana warrisi, Cruziana* sp. B, and *Diplichnites binatus.* In Scopes Range, *R. latus* is mainly confined to the quartz-rich sandstones in the middle part of the Scopes Range Beds. It may be associated with rare occurrences of *Cruziana* sp. A, *Diplichnites* sp. B and *Monomorphichnus* sp. A stratigraphically higher unit of the Scopes Range Beds includes the isolated occurrence of *Diplichnites* sp. A. The *Rusophycus* occurrences in the Bynguano Quartzite are of broadly similar 'Tremadoc' age (Webby, *in* Shergold *et al.* 1982, pp. 220-21), while the occurrences in the lower part of the Rowena Formation are of slightly younger, possibly early Arenig age. The *Rusophycus* associations in the middle part of the Scopes Range Beds probably span a similar interval (Fig. 1).

The uppermost Cambrian-Lower Ordovician clastic successions in western New South Wales have been interpreted as having accumulated in a major delta complex (Webby, 1976; 1978). The deposits were spread in successive influxes across the Gnalta Shelf (a remnant of the former continental shelf) from uplifted land areas of Gondwanaland to the south and west (Fig. 1). The proportion of non-marine deposits (and coarse clastics) is greatest in the Scopes Range succession reflecting its more proximal position in the delta system. The most marine depositional conditions are of very shallow water type, recorded at three stratigraphic levels within the Scopes Range succession, and including representatives of the *Rusophycus, Skolithos* and *Arthrophycus*-dominated trace-fossil assemblages. Occasionally shells of inarticulate brachiopod *Trigonoglossa* and a gastropod may also be associated.

In the more markedly marine Bynguano Range succession, *Rusophycus, Skolithos* and *Arthrophycus* trace-fossil assemblages dominate the shallowest marine parts of the sequence but there is also a short-lived phase of more open marine conditions with a varied shelly fauna (Webby, *in* Shergold *et al.*, 1982, text-figs 8-9). This occurs in the middle part of the Rowena Formation. The fauna includes the trilobites *Carolinites, Asaphellus, Prosopiscus* and protopliomerids, the brachiopods *Obolus, Lingulella, Ectonoglossa,* gastropods and the conodonts *Microcoelodus, Chirognathus* and *Aphelognathus.* It closely resembles the fauna occurring in the Tabita Formation at Mount Arrowsmith (Fig. 1), and in the Horn Valley Siltstone of the Amadeus Basin, central Australia.

Fig. 1. Diagram to show location of arthropod traces in stratigraphic columns of the Upper Cambrian — Lower Ordovician succession in western New South Wales. Arthropod traces are typically represented in the 'deltaic facies' of the Bynguano Range and Scopes Range sections. Key to arthropod traces shown by letter symbols in stratigraphic columns, as follows: a, *Cruziana warrisi;* b, *Cruziana* sp. A; c, *Cruziana* sp. B; d, *Diplichnites binatus;* e, *Diplichnites* sp. A; f, *Diplichnites* sp. B; g, *Monomorphichnus* sp.; h, *Rusophycus latus.* Locality map and generalized palaeogeographic map for region during Lower Ordovician (Tremadoc-Arenig) time also shown.


BYNGUANO RANGE
SCOPES RANGE
MT. ARROWSMITH
Predominantly fluvial
Deltaic (restricted marine)
Predominantly fluvial
Open marine
Fluvial
Deltaic (restricted marine)
Fluvial
Fluvial
Pingbilly Fm.
Tabita Fm.
Yandaminta Quartzite
Pre-Palaeozoic Basement
Rowena Formation
Bynguano Quartzite
Naatumbulla Sandstone
Caanigan Fm.
Scopes Range Beds
Pre-Palaeozoic Basement
e
bfgh
h
acdh
h
h
0
500m
VERTICAL SCALE
ARENIG - ?LLANVIRN
LATE-CAMBRIAN-TREMADOC
Pre-Palaeozoic Basement
Mt. Arrowsmith
Open marine
TASMAN GEOSYNCLINE
GNALTA SHELF
LAND
Copper Mine Ra.
Bynguano Ra.
Fluvial-Deltaic Complex
Scopes Ra.
Broken Hill
NEW SOUTH WALES
SYDNEY
GENERALIZED LOWER ORDOVICIAN PALAEOGEOGRAPHY

Of the eight trace-fossil species described from the Lower Ordovician of western New South Wales, only one, the 'rest mark' *Rusophycus latus,* is commonly represented in the successions. There is frequently so much activity that entire bedding surfaces are covered with scratchings of the arthropod (Fig. 2A). Association of *Skolithos* in some beds directly below the surface of colonization raises the question of whether the activity was more concerned with digging for the soft-bodied *Skolithos* animal than with resting, sheltering or concealment from predators. The occasional association of desiccation cracks on undersurfaces with *Rusophycus* testifies to the shallowness of marine conditions, probably implying deposition in the intertidal zone. None of the eight arthropod trace-fossil species can be demonstrated to represent the activity of particular trilobites.

The *Rusophycus*-bearing Bynguano Quartzite and its equivalents in the Scopes Range may be regarded as correlatives of the Pacoota Sandstone of the Amadeus Basin (Wilson, 1967; Warris, 1967, unpubl.; Webby, 1978; Webby *et al.,* 1981), and probably also of the Tomahawk Beds of the Georgina Basin. The form illustrated by Ranford *et al.* (1965) and Wells *et al.* (1970) as *Cruziana* from the Pacoota Sandstone is more correctly referable to *Rusophycus.* Indeed it closely resembles the New South Wales ichnospecies described herein as *R. latus.* Similarly the 'rest mark' from the Tomahawk Beds referred to *Cruziana omanica* by Seilacher (1970) is erroneously assigned since it does not exhibit the 'procline furrows' of the holotype from Oman. Based on accepted modern taxonomic practices (Osgood, 1970; Birkenmajer and Bruton, 1971; Bergström, 1973; Crimes, 1975; Crimes *et al.*, 1977), the Tomahawk specimen should be grouped as a *Rusophycus.* A similar variety of *Rusophycus* is illustrated by Hill *et al.* (1969, pl. V, fig. 10) from the Ordovician (formation not stated) of the Toko Range, Georgina Basin. These Georgina and Amadeus Basin forms should perhaps be equated with *R. latus.*

TOWARDS AN AUSTRALIAN ORDOVICIAN ARTHROPOD TRACE-FOSSIL SUCCESSION

In the light of Seilacher's (1970) claims that arthropod traces of the *Cruziana* and *Rusophycus* type can be useful guide fossils, it is perhaps worth noting that a crude ichnostratigraphy is already recognizable in Australian Lower-Middle Ordovician clastic successions. First, in the Lower Ordovician (Tremadoc-Lower Arenig) sequences like the Bynguano Quartzite, Pacoota Sandstone and Tomahawk Beds, there is an abundance of occurrences of *Rusophycus latus* type — forms which may be assigned to Seilacher's *petraea* group.

Secondly, in Arenig-Lower Llanvirn successions such as the Nora Formation of the Georgina Basin and the Stairway Sandstone of the Amadeus Basin, there are representatives of Seilacher's *rugosa* group. A well preserved *Cruziana* illustrated by Hill *et al.* (1969, pl. V, fig. 9) from the Nora Formation is attributable to *C. rugosa,* and a *Cruziana* in the Stairway Sandstone (Ranford *et al.*, 1965; Conybeare and Crook, 1968) is, according to Ritchie and Tomlinson (1977), an occurrence of *C. furcifera.*

Thirdly, in the Middle Ordovician succession of the Georgina Basin, Draper (1977; 1980) has recorded two distinctly different assemblages. A variety of arthropod traces occurs in the lower part (sub unit A) of the Carlo Sandstone, including *Cruziana, Dimorphichnus, Diplichnites, Merostomichnites* and *Rusophycus.* The representatives of *Cruziana* and *Rusophycus* have the appearance of members of Seilacher's (1970) *imbricata* group. A markedly different species of *Rusophycus* occurs in the overlying Mithaka Formation. The large, oval, bilobate specimens may be in excess of 300 mm long, and are characteristically differentiated into an inner area with traces of segmentation (imprints of coxae) and broad outer paired lobes covered with scratchings. They exhibit a range of morphology, most commonly resembling *R. carleyi* but also including specimens with similarities to *R. dilatatus.* Seilacher's (1970) original description of this latter species is based in part on a photograph of a large specimen from the Toko Range of the Georgina Basin. Draper (1980) has regarded the Mithaka forms of *Rusophycus* as belonging to Seilacher's (1970) *carleyi* group, but they could just as appropriately be linked to the *almadenensis* group. For instance Ritchie and Tomlinson (1977) have referred to a *Cruziana* from a similar or slightly younger stratigraphical horizon, in the Carmichael Sandstone of the Amadeus Basin, as *C.* cf. *almadenensis.*

In very generalized terms the Australian Lower-Middle Ordovician succession of 'groups' (*petraea* → *rugosa* → *imbricata* → *carleyi* or *almadenensis*) is comparable with that depicted by Seilacher (1970) for European and North African sequences. However at the ichnospecies level few forms are common to both European/North African and Australian successions. None of the European 'Tremadoc' representatives of *Cruziana (C. semiplicata, C. furcifera, C. goldfussi, C. tortworthi, C. breadstoni)* or *Rusophycus* described or illustrated by Crimes (1970b; 1975) and Baldwin (1977) appears to be represented in the New South Wales 'Tremadoc' ichnofaunas.

Systematic Descriptions

Type specimens are housed in the palaeontological collection of the Department of Geology and Geophysics, University of Sydney, and have the prefix SUP. For grid references to fossil localities cited in the foregoing descriptions see 1:100,000 Orthophotomap Series — Topar 7334 (first edit., 1979), Nuchea 7335 (first edit., 1980) and Bunda 7434 (first edit., 1980).

Genus *Cruziana* d'Orbigny 1842

Type species: C. rugosa d'Orbigny 1842

Cruziana warrisi sp. nov.

Fig. 2**B**

Material: Holotype (SUP 16897) is from the Bynguano Quartzite just north-west of Bynguano Bore, Gnalta (grid ref. XL 2258). Another specimen (SUP 43900) from the Scopes Range Beds, 9 km south-east of Churinga (grid ref. XK 7284) may be tentatively assigned to the species.

Etymology: After B. J. Warris, the original collector of the holotype.

Description: Two large, moderately deep, bilobate trails intersecting one another almost at right angles, preserved in convex hyporelief; at least 140 mm long, up to 84 mm wide and 20 mm deep. Each lobe exhibits numerous fine, close-spaced ridges running inwards and slightly backwards to centre line. V-angle (angle subtended by adjacent ridges of each lobe) varies from 120° to 180°. Ridges may be continuous and parallel across the lobe, or discontinuous where they are intersected by more continuous ridges; sometimes a prominent criss-cross pattern of ridges exhibited with intersections mainly at angles of 25-40°; continuous ridges (latest-formed scratchings) are usually less markedly backwardly inclined, and may be paired; equally strongly impressed, and spaced from 1.5-1.8 mm apart; these paired ridges seem to define ?anterior side of sets each comprising five or more ridges. Much smaller trails and burrows of indeterminate type cut across holotype; one straight, faintly bilobated, narrow trail, 2 mm wide, extends along the flank of one of the *Cruziana* trackways, and has appearance of lateral ridge. However it is not continuous along length of trackway and is not duplicated on the other flank of trackway; nor is it seen in other trackway. From manner in which this small trail cuts some ridges and not others, it appears to postdate formation of *C. warrisi.*

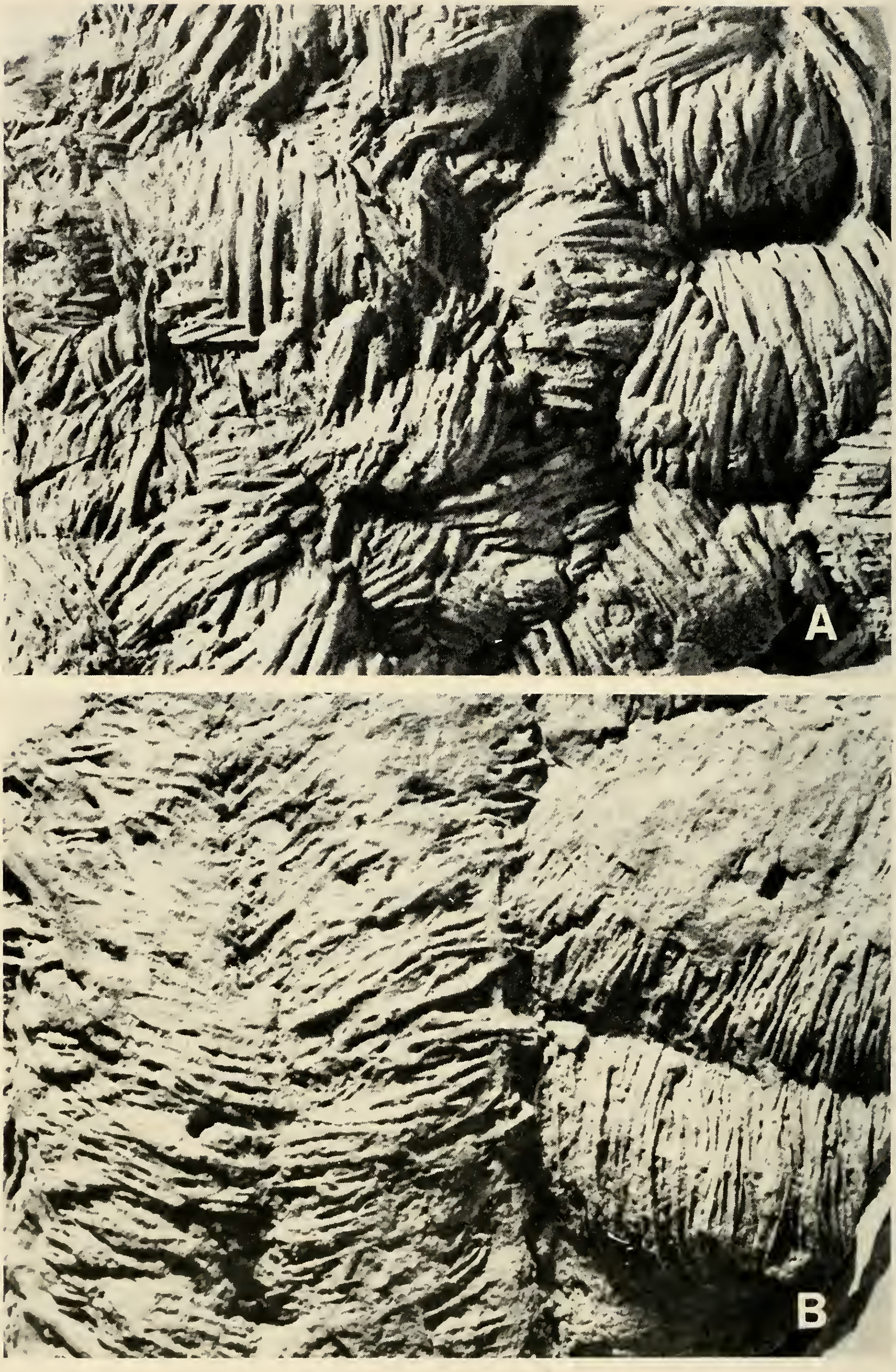


Fig. 2. **A**, undersurface of bedding plane (convex hyporelief) with activity of *Rusophycus latus* sp. nov.; from middle part of Scopes Range Beds west of Bilpa; SUP 42937, x0.75. **B**, *Cruziana warrisi* sp. nov., holotype, SUP 16897, x1.

Remarks: C. warrisi has a high V-angle, a narrow spacing between ridges and forms a relatively deep burrow, features consistent with the producer moving at relatively slow speed through the surface sediment. Crimes (1975, p.36) has noted that the forms of *Cruziana semiplicata* with higher V-angles were more deeply impressed, and usually do not show lateral ridges because in the burrowing technique its head was tipped downward. Consequently the 'general spines' did not make contact with the sediment. To what extent the very high V-angle is due to the ploughing activity of an head-down rather than tail-down arthropod (see Seilacher, 1970, fig. 4) is unknown. However no other large variety of *Cruziana* has such a high V-angle. The widely distributed Lower-Middle Ordovician species, *C. furcifera,* has a much lower V-angle, and coarser and more markedly anastomosing ridges (Crimes, 1968).

Cruziana sp. A
Figs 3**A** and 4**B**

Material: One well-preserved specimen (SUP 42927) is from middle part of Scopes Range Beds, south side of track, 6 km west of Bilpa (grid ref. XK 2774). A second incomplete and rather poorly-preserved specimen (SUP 42929) comes from the Scopes Range Beds, 9 km south-east of Churinga (grid ref. XK 7284).
Description: These shallow, bilobated trails are preserved as convex hyporeliefs. In well-preserved specimen, trail is slightly asymmetrical (Fig. 3**A**), 70 mm wide, 75 mm long and with a depth of up to 3 mm; V-angle from 80-100°; ornament of fine, paired, gently curved, obliquely (backwardly and inwardly) directed ridges; pairs spaced 2.5-3.5 mm apart; much closer spacing between anterior and posterior ridges of each pair, usually 1.0 mm apart; posterior ridge of pair usually more prominent. Only one lobe of second specimen is preserved (Fig. 4**B**); it is 160 mm long, and has a depth not exceeding 6 mm.
Remarks: The asymmetrical form of this shallowly-impressed variety of *Cruziana* may have been produced by an animal being swung slightly sideways by an obliquely-aligned current as it moved forward.

Cruziana sp B.
Fig. 4**A**

Material: One specimen (SUP 42930b) from the middle part of the Bynguano Quartzite, 1.5 km west of Bynguano Bore, Gnalta (grid ref. XL 2158).
Description: This small variety of *Cruziana* is preserved in convex hyporelief cutting across the anterior part of a large *Rusophycus,* and apparently post-dating its formation. The trail is strongly bilobated, 42 mm long, up to 16 mm wide and 4.5 mm deep. It exhibits very fine anastomosing ridges running obliquely across lobes and spaced 0.5-1.0 mm apart; V-angle is approximately 60-80°.
Remarks: Cruziana sp. B appears to be most closely comparable with the 'small variety of *Cruziana*' figured by Selley (1970, pl. 1b) from Lower Ordovician sandstones in Jordan. However lateral ridges seem to be present on the Jordanian specimens, not seen in the N.S.W. material.

Ichnogenus *Diplichnites* Dawson 1873
Type species: D. aenigma Dawson 1873

Diplichnites binatus sp. nov.
Fig. 3**B**

Material: Holotype (SUP 42926) is from the middle part of the Bynguano Quartzite in the Bynguano Range, near Mootwingee (grid ref. XL 2647).

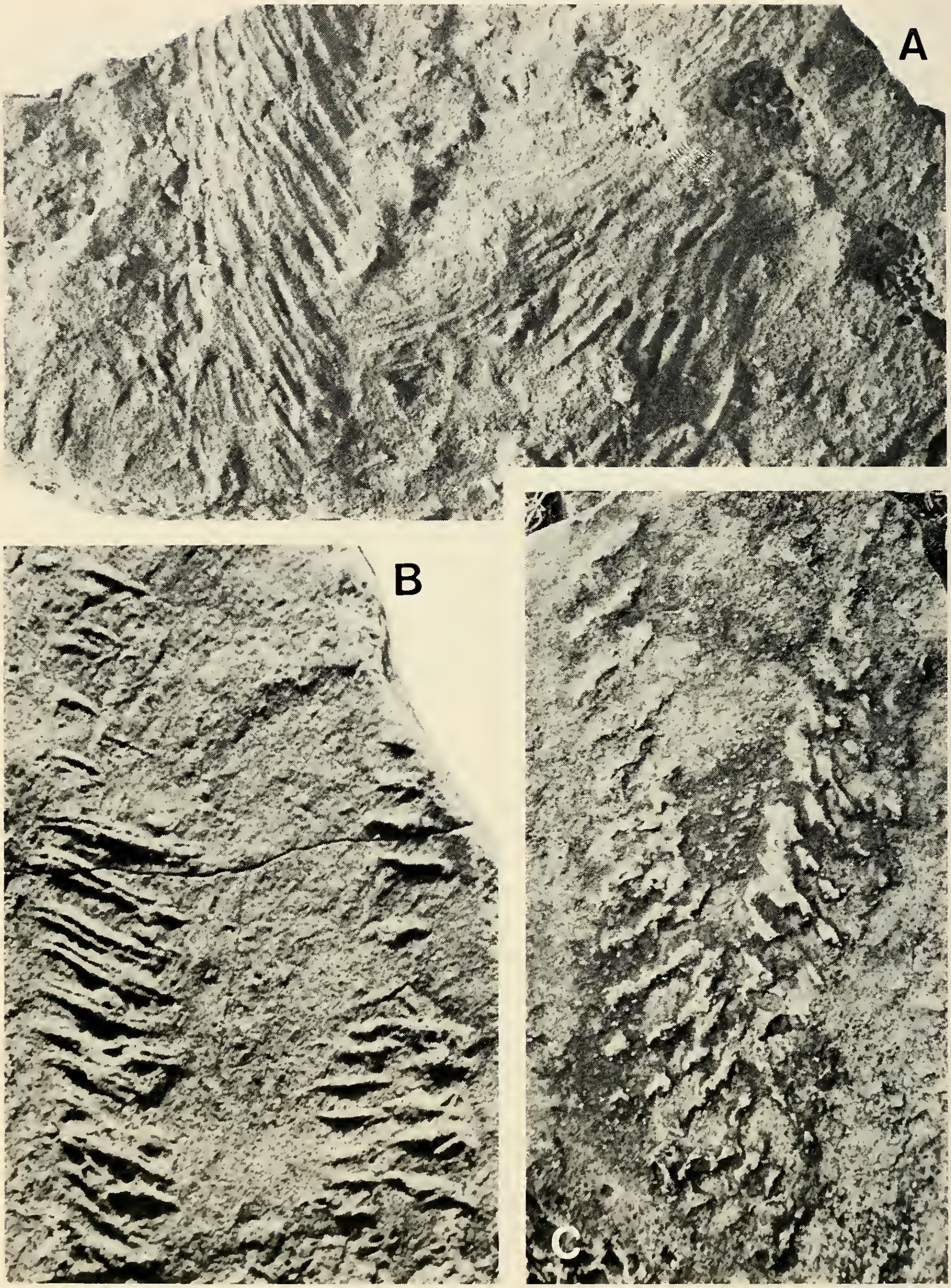


Fig. 3. **A**, *Cruziana* sp. A, SUP 42927, x1. **B**, *Diplichnites binatus* sp. nov., holotype SUP 42926, x0.75. **C**, *Diplichnites* sp. A, x0.25.

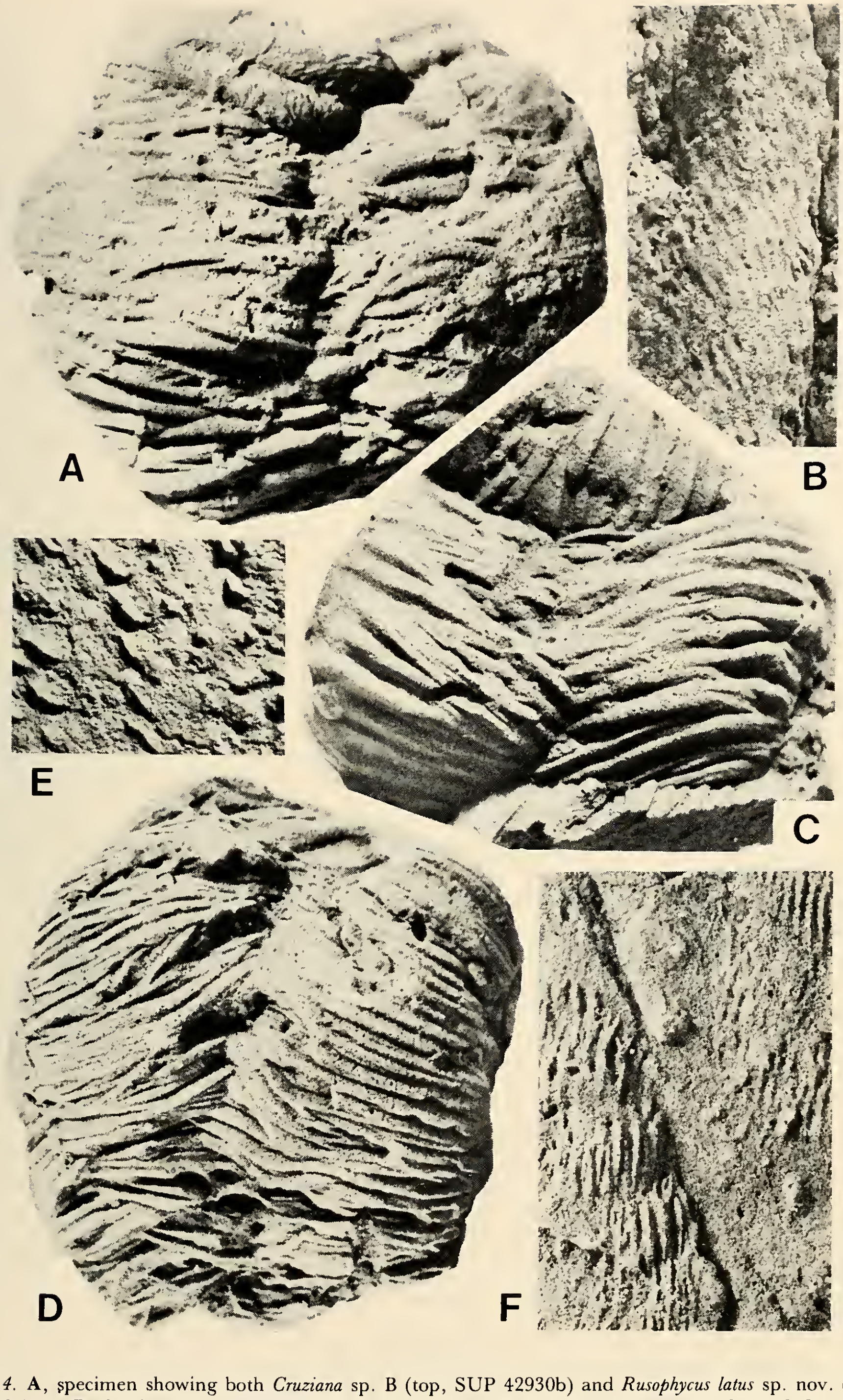


Fig. 4. **A**, specimen showing both *Cruziana* sp. B (top, SUP 42930b) and *Rusophycus latus* sp. nov. (SUP 42930a), x1. **B**, *Cruziana* sp. A, SUP 42929, x0.75. **C**, *Rusophycus latus* sp. nov., paratype SUP 42933, x1. **D**, *Rusophycus latus* sp. nov., holotype SUP 42932, x1. **E**, *Diplichnites* sp. B, SUP 42931, x0.75. **F**, *Monomorphichnus* sp., SUP 42928, x1.

Etymology: With reference to the bifid imprints probably representing two-clawed limbs.

Description: Trackway preserved in convex hyporelief; overall width 72 mm and 145 mm long; consists of two well-separated parallel rows of slightly diagonally-orientated imprints, some 23 mm apart. Regular, long, paired, equally prominent, straight to slightly sigmoidal ridges (or imprints) may extend completely across row, up to 27 mm long, or may be shorter, less regularly spaced and less uniformly raised, single linear markings; ridges of individual pairs spaced 1.5-2.5 mm apart; pairs of ridges from 2 to 5 mm apart. No apparent ordering of imprints into sets. V-angle is from 150° to 170°; presumably direction of gape is direction of movement (Crimes, 1970a).

Remarks: Although two-clawed limbs seem to have been responsible for producing the paired ridges, they lack continuity along the entire length of the trackway. Their change to single ridges may be explained by rotation of the limbs (Osgood and Drennan, 1975). The relatively great length of the paired claw markings and the relatively short distance between successive imprints (implying a short stride) may, following Crimes (1970a), suggest that the animal was moving relatively slowly across the sea floor. Possibly it was walking but with a fair component of drag of its two-clawed limbs. The high V-angle supports this view.

This trackway is distinguished from other described Ordovician representatives of *Diplichnites* by its large size and long, parallel, equally prominent bifid imprints. Only *Diplichnites* sp. A is larger (see below).

Diplichnites sp. A
Fig. 3**C**

Material: One specimen preserved in convex hyporelief from the upper part of the Scopes Range Beds near Bilpa (grid ref. XK 3175).

Description: This very large trackway narrows in width along its length; it has a maximum width of 185 mm and length of 400 mm. Two rows of diagonally orientated imprints well separated at one end, but gradually merge towards other end of trackway; alignment of imprints gives V-angle of 80-100°; number of imprints across width of row variable — may be just one elongate ridge up to 56 mm long, or up to three discrete irregular scratch marks. Individual ridges are from 16-24 mm apart along the row; no evidence of paired ridges.

Remarks: This large trackway may be interpreted as recording an arthropod moving from a walking or striding to a swimming mode of locomotion (Crimes, 1970a). The comparatively large spacing between individual ridges of each row, and the moderately low V-angle (as compared for instance with *D. binatus*) suggests that the animal was moving at a reasonable speed as it lifted off to assume a swimming mode. It does not however show a marked decrease in length of claw markings immediately prior to lift off as seems to have been suggested by Crimes (1970a, fig. 6).

From their respective dimensions and the nature of their imprints, the trackways of *D. binatus* and *D.* sp. A seem unlikely to have been produced by the same type of arthropod. It they were produced by trilobites they must have been remarkably large forms, significantly larger than any so far collected from Ordovician successions in western New South Wales. The *D.* sp. A animal must have been at least 185 mm wide and possibly of the order of one and a half times longer.

Diplichnites sp. B.
Fig. 4**E**

Material: One specimen (SUP 42931) from middle part of Scopes Range Beds, south side of track, 6 km west of Bilpa (grid ref. XK 2774).

Description: This specimen, preserved in convex hyporelief, shows short, oblique, crescent-shaped markings in three rows; a complementary fourth row is not preserved. Trackway attains maximum width of 48 mm and one row of imprints is traceable over bedding surface for a distance of 110 mm.

Remarks: In terms of the pattern shown by Seilacher (1955, Abb. 1f) for an arthropod trace from the Lower Silurian Nereiten-Schichten of Barrancos, Portugal, this incomplete trackway may be interpreted as being produced by an animal moving forward but, because of a cross current, with its body aligned slightly obliquely to the direction of movement. Consequently the sets of imprints on one side of the trackway, at least, markedly overlap one another.

Ichnogenus *Monomorphichnus* Crimes 1970a

Type species: M. bilinearis Crimes 1970a

Monomorphichnus sp.

Fig. 4**F**

Material: One specimen (SUP 42928) from the middle part of the Scopes Range Beds, south side of track, 6 km west of Bilpa (grid ref. XK 2774).

Description: Specimen preserved in convex hyporelief and shows separate sets of ridge-like impressions to either side of deep, obliquely-aligned groove; each set with seven or more parallel ridges but they are not continuous because ripple-like annulations intersect them almost at right angles; these latter are spaced at 10-13 mm apart. One of the sets exhibits clear differentiation into paired ridges, each pair with one more prominently impressed than the other; spacing between more prominent or paired ridges usually 2.5 mm apart. In the other set, the ridges are single and spaced from 1.5 to 2.0 mm apart.

Remarks: From the morphological similarities of *Cruziana* sp. A and *Monomorphichnus* sp., and their occurrences in the same horizon and locality in Scopes Range, it may be suggested that the two forms were produced by the same variety of animal. If *M.* sp. represents a structure formed by an arthropod being swept sideways in the current, as Crimes (1970a) has argued, then the number of pairs of ridges produced in a set may approximate the number of limbs of the animal. This would seem to suggest that the New South Wales *Monomorphichnus* animal had at least seven walking legs.

Morphological differences in spacing of ridges and the presence or absence of paired ridges may be explained by the orientation of the animal's appendages changing slightly as it was swept across the surface from one set to the other.

Ichnogenus *Rusophycus* Hall 1852

Type species: Fucoides biloba Vanuxem 1842.

Rusophycus latus sp. nov.

Figs 2**A**, 4**A**, 4**C-D**, 5**A**, & **C**, 6-7

?1970 *Cruziana omanica* Seilacher p.466 fig. 9b (*non* fig. 9a)

1972 'Trails of trilobites of Cambrian age' Hill, p.16, fig. 10a.

Material: Holotype (SUP 42932) from middle part of Scopes Range Beds, 5 km west of Bilpa (grid ref. XK 2874) and six paratypes (SUP 42930a; 42935-36; 42941; 42948; 43905) from middle part of Bynguano Quartzite 1.5 km west of Bynguano Bore, Gnalta (grid ref. XL 2158) and two paratypes (SUP 42933; 43903) from lower part of Bynguano Quartzite immediately west of Bynguano Bore (grid ref. XL 2257). SUP 42934 (collected by D. F. Branagan) and 43903 probably also come from this latter horizon and locality. Other specimens from same locality and horizon as holotype

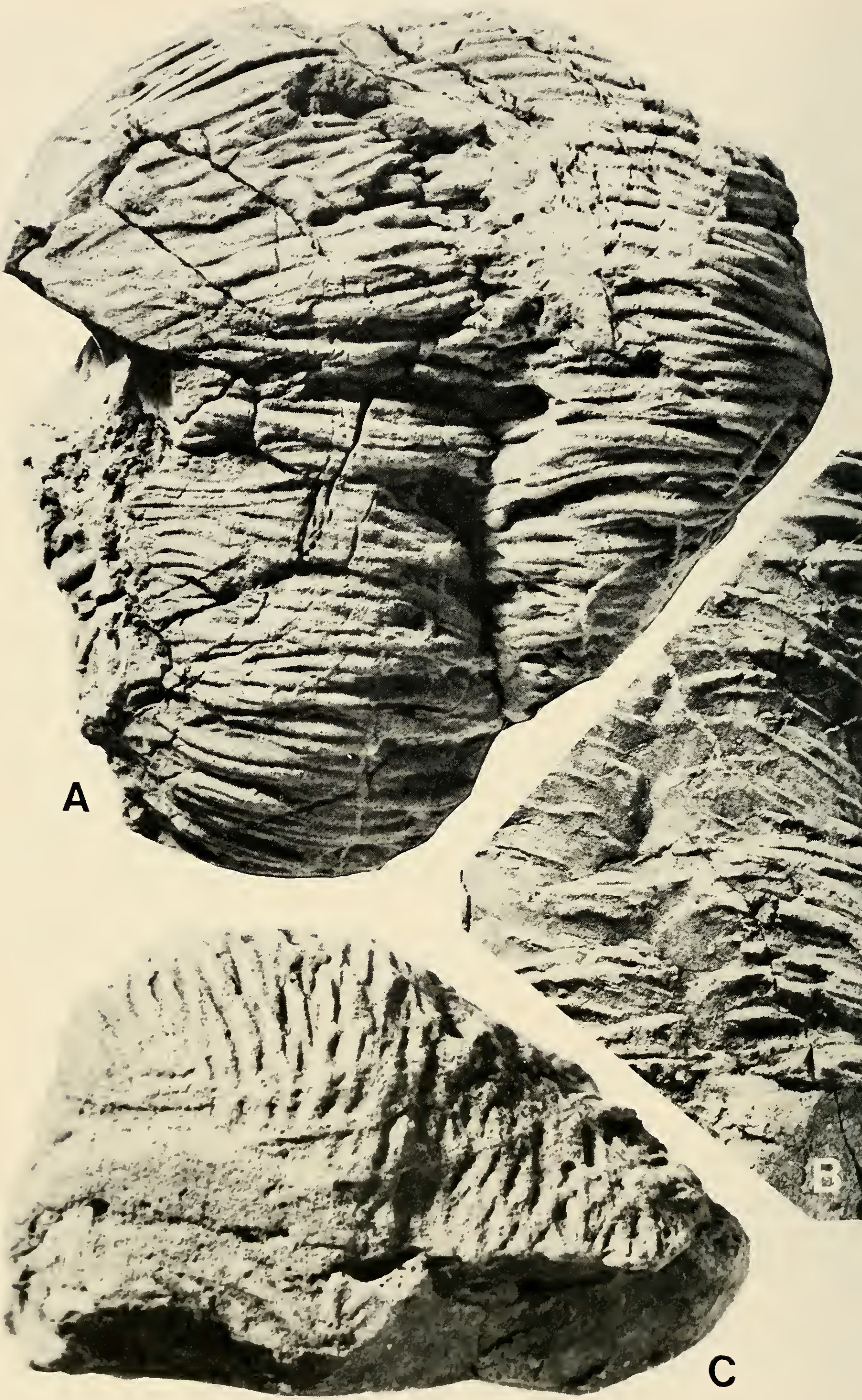

A
B
C

Fig. 6. Rusophycus latus sp. nov., SUP 42934, x0.5.

include SUP 42939-40, 42942, 42944, 42946, 43902, 43907-08, 43910. Three of these, SUP 42939, 42944 and 42946 also designated paratypes. At a slightly higher horizon in the middle part of the Scopes Range Beds, 6 km west of Bilpa (grid ref. XK 2774) specimens SUP 42943, 43901, 43904 and 43909 occur. SUP 42947 comes from middle part of the Bynguano Quartzite in the Bynguano Range (grid ref. XL 2647), and SUP 42945 and 43906 are from the Bynguano Quartzite cropping out on the old Broken Hill-White Cliffs coach road, Bynguano Range (grid ref. XL 2844).

Etymology: Alluding to its width characteristically being slightly greater than its length.

Description: Large bilobated traces preserved in convex hyporeliefs; varying from 36 to 120 mm in length, and from 43 to 115 mm in width; most commonly from 66 to 88 mm in width and from 55 to 84 mm in length (Fig. 7); following Crimes (1970b, p. 114), the shape factor (length divided by breadth) is 0.85. Depth varies from 8 to 38 mm, usually 9 to 27 mm (Fig. 7). Outline varies from transversely elliptical through subquadrate to heart shaped; widest and deepest part of trace usually in anterior half; in profile deeper burrows are markedly asymmetrical, and may show traces of lateral ridges (Fig. 5**C**). Convex lobes usually clearly differentiated by longitudinal median furrow; each lobe exhibits large number of predominantly transversely-directed coarse-textured ridges; but axially these ridges may deflect slightly forwards or backwards (Figs 4**C-D**). Ridges may be continuous or discontinuous across lobe; usually spaced 2.5 to 4 mm apart; frequently appear to be bifid or even trifid. Apart from a reduction in length consistent with narrowing of the lobes towards anterior and posterior

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Fig. 5. **A**, *Rusophycus latus* sp. nov., paratype SUP 42935, x1. **B**, coarse-textured, wide-spaced scratchings representing a type of moving trail probably made by same animal as produced *R. latus* markings; SUP 42938, x0.75. **C**, *Rusophycus latus* sp. nov., in side view; paratype SUP 42936, x1.

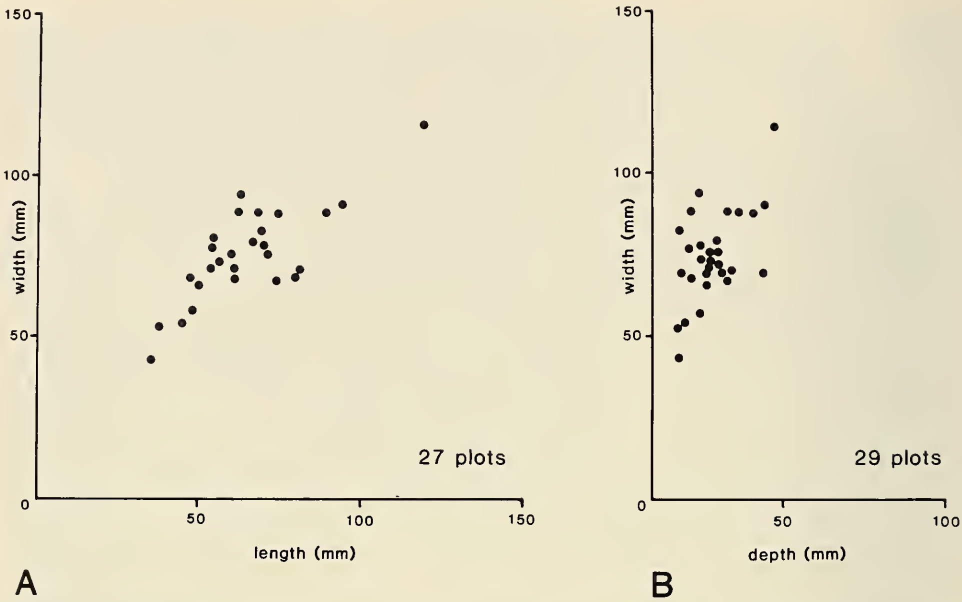

Fig. 7. Scatter diagrams of width against length (**A**) and width against depth (**B**) for specimens of *Rusophycus latus.*

margins, ridges show no apparent differentiation in spacing or form; usually about 20 to 35 ridges are represented; in the largest specimens up to 45 (Fig. 5**A**); occasionally ridges appear to be bundled into sets of three or four.

Remarks: This very common trace fossil in western New South Wales Lower Ordovician successions sometimes extends to entirely covering bedding surfaces with its activity (Fig. 2**A**). It exhibits a wide range of morphology, but no evidence of a gradation into a *Cruziana*-type furrow of the *C. omanica* type. The only markedly different type of trace which exhibits the same kind of coarse-textured scratchings is illustrated in Fig. 5**B**. This specimen comes from the same locality and horizon as the holotype. From the wide spacing of scatchings it probably represents some sort of moving trail, but not a typical *Cruziana.*

Crimes (1970b) has claimed that in ascending from the Upper Cambrian to the Arenig, British occurrences of *Rusophycus* show changes in form and gradual increases in mean width and mean 'shape factor' (length divided by breadth). They are therefore viewed as having biostratigraphic utility for distinguishing between Upper Cambrian, Tremadoc and Arenig strata in otherwise unfossiliferous successions. Crimes represented the 'shape factor' as rising from 1.5 in the Upper Cambrian to 2.0 in the Lower Ordovician. However, even Crimes's Upper Cambrian value is much higher than the 'shape factor' of 0.85 for the 'Tremadoc — lower Arenig' occurrences of *Rusophycus* from western New South Wales. It leads to the conclusion that Crimes's scheme is of localized rather than more wide-ranging biostratigraphical significance for correlating otherwise unfossiliferous Lower Palaeozoic sequences.

Acknowledgements

This study has been supported by funds from University of Sydney Research Grants and the Australian Research Grants Committee (A.R.G.C. grant no. E82/15297.

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